PTO 01-[PTO 2005 4429]

Japan Patent

(Number of Document Heisei 6-13597)

AMPLIFICATION TYPE SOLID STATE IMAGE PICKUP ELEMENT

[増幅型固体撮像素子]

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UNITED STATES PATENT AND TRADEMARK OFFICE

Washington, D.C. June 2005

Translated by: Schreiber Translations, Inc.

Country : Japan

Document No. : Heisei 6-13597

Document Type : Patent application

Language : Japanese

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Applicant : Rikoh Corp

IPC : H01L 27/146, H04N 1/028, 5/335

Application Date : June 26, 1992

Publication Date : January 21, 1994

Native Title : [増幅型固体撮像素子]

English Title : AMPLIFICATION TYPE SOLID STATE IMAGE PICKUP ELEMENT

(54) [Title of the invention]

AMPLIFICATION TYPE SOLID STATE IMAGE PICKUP ELEMENT

(57) [Abstract]

[Purpose]

It decreases the output characteristics caused by a large accumulation capacity and improves the photo sensitivity.

[Structure]

Photoelectric conversion unit PD generates photoelectric charge corresponding to the amount of incoming light (incidence of light). PD reset switch S1 is used to fix one side of electrical potential of PD and the electrical potential of control input terminal of the amplification element to respective optional electrical potential for an optional period. Control unit Sc electrically switches by the connection and disconnection of capacitance part of photoelectric conversion unit in which is accumulated photoelectric charge generated by photoelectric converting unit PD and the capacitance part of amplification element in which is accumulated the photoelectric charge to be introduced into the control input terminal of amplification element.

[Scope of the patent claims]

[Claim item 1]

In the amplification type solid state image pickup element equipped with photoelectric conversion unit which generates photoelectric charge dependent upon the incoming amount of light wherein, it introduces said photoelectric charge into the control input terminal of amplification element formed for each image concept and amplifies and reads the electric signals dependent upon the amount of incoming light,

it is the amplification type solid state image pickup element characterized as comprising capacitance part of photoelectric conversion unit which accumulates photoelectric charge generated by the aforementioned photoelectric conversion unit, capacitance part of amplification element in which is accumulated the photoelectric charge to be introduced into the control input terminal of amplification element, the optional control unit which enables the switching of electrical connection and disconnection of said both capacitance parts and is set up for each pixel.

[Claim item 2]

It is the amplification type solid state image pickup element described in claim item 1 characterized such that the magnitude of the accumulated capacity of photoelectric charge introduced into aforementioned amplification element is smaller than the capacity magnitude to be accumulated of photoelectric charge generated by photoelectric conversion unit.

[Claim item 3]

It is the amplification type solid state image pickup element described in claim item 1 characterized such that

In addition to the control unit set up at each aforementioned pixel, other control unit which enables the electrical potential of control input terminal of amplification element to be fixed for optional period and to optional electrical potential.

[0001]

[Technical field]

This invention relates to the amplification type solid state image pickup element and in greater details, relates to reading devices of light information signals of facsimile, color copying

machine, video camera and the like, and solid state image pickup elements.

[0002]

[Prior arts]

As to the traditional amplification type solid state image pickup element, the light information signals obtained by photoelectric conversion unit is amplified within the same pixels, and is XY address type area image sensor which reads via vertical and horizontal scanning switch circuits. Figure 17 shows the structure of one pixel of the internal amplification type solid state image pickup element of the prior art (hereafter called a traditional element). Figure 18 shows its equivalence circuit. In the figure, 501 is P type single crystal silicon substrate, 502 is (n+) area (n+ expresses the higher portion of density of n shaped semiconductor area), 503 silicon oxide film, 504 first aluminum film, 505 low resistance polysilicon film, 506 interlayer insulating film, 507 second aluminum film.

[0003]

One pixel of the traditional element comprises (n+) P photo diode PD as photoelectric conversion unit, switch Trs for PD resetting, 3 units of amplification element Ta and n channel MOS electric field effect type transistor with vertical selection switch Ty.

Horizontal scan switch Tx is set up for each vertical signals line.

As to aforementioned traditional element, in principal, photoelectric charge is generated dependent on the amount of incoming light as the reverse bias state of PD, and this photoelectric charge is accumulated in the capacitance part Cpd of PD and capacitance part Cg of amplification element Ta and the like, then, the electrical potential of gate electrode which is control input terminal of Ta is changed, photo electric signals which matched the light

information is amplified by current and read, and the basic operation is shown in the following.

[0004]

In resetting period, one side of electrical potential Vp of photoelectric conversion unit PD is set up at the initial stage value Vrs (positive electrical potential) by setting Trs in the "ON" state. In accumulation period, by setting Trs in OFF state, the state of Vp becomes electric potentially floating (hereafter called floating). At this time, among electrons and positive electron holes excited by PD due to light irradiation, electrons are accumulated in Cpd and Cg and the like, and positive electron holes flow out into the substrate. Hence, electrical potential of Vp decrease corresponding to the amount of incoming light. Vp is always electrically connected with the gate electrodes which are a control input terminal of amplification element Ta, hence, the electrical potential Vo of gate electrode of Ta and the electrical potential of Vp always become the same electrical potential. Due to the fact that Vp decreased, Vg decreases at the same time, current amplified corresponding to Vp of PD can be read via Ty and Tx. As to the aforementioned traditional element, maximum current flows in a dark state (in the state where no light comes into PD), and as the amount of incoming light increases, Vg decreases. Output current decreases showing the negative type characteristics, however there are some traditional elements wherein depending on the type of photoelectric conversion unit, amplification element types and method of signal output circuit, the electrical potential of control input terminal for amplification element climbs and output current amplifies.

[0005]

In the traditional element, as the important characteristics required as solid state image pickup element, there is photoelectric conversion characteristics, the characteristics values are

calculated according to the following calculation. As to the entire accumulation capacity Cst in which photoelectric charge Qp converted photo electrically dependent on the amount of incoming light is accumulated, it can be expressed as the sum total of static electricity capacity Cpd of photo diode PD, gate capacity Cg of amplification element TA, capacity between Gate. Drain of switch trs for resetting rsCg-d, capacity rsCd-sub between drain. Substrate. In the above described each capacity, rsCg-d, rsCd-sub are parasitic capacity which are expected to be zero. According to the above, Cst can be expressed as the following formula (1).

[0006]

See the original for formula (1)

Hence, the electrical potential change ΔVp of the both end of photo diode is as in the following formula (2) in proportion to the amount of incoming light.

See the original formula (2)

Accordingly, the gate electrical potential Vg of amplification element Ta is as follows:

see the original formula (3)

Output voltage V9 if the reading circuit gain is set to be Av, threshold value to be voltage Vr after amplifying, becomes as in the following formula (4):

See the original formula (4)

And, as to the output current after amplifying, setting load resistance to be Rl, formula (5) is as follows:

See the original formula (5)

[0007]

according to the aforementioned formula (4) and formula (5), as to change amount Δs of output

voltage dependent on the increase and decrease of incoming light and change amount ΔIs of output current, entire accumulation capacity Cst is greatly dependent on it, one can tell that the larger the Cst, the smaller ΔVs.ΔIs. In the traditional element, the entire accumulation capacity inevitably becomes large since it is the sum total of static electricity capacity of photo diode, gate capacity of amplification element, and parasitic capacity, and change amount ΔVs.ΔIs of output amount after amplifying becomes small, thus photo sensitivity characteristics decreases which is a defect.

[0008]

As the pixel numbers of solid state image pickup element increases and its speed increases, the incoming light amount into one pixel decreases and the photoelectric charge amount Qp with photoelectric conversion also decrease. On the other hand, high gradation property is demanded, and large output characteristics, that is, in the traditional elements, high photoelectric sensitivity characteristics is expected. In the traditional element, attributed to the large entire accumulation capacity, that photoelectric sensitivity deteriorates causes large problems in increasing the pixels, speed, and gradation property of solid state image pickup element.

[0009]

[Purpose]

This invention was done in view of the above described situations, and the purpose was to provide amplification type solid state image pickup element which decreases the reduction of output characteristics caused by a large accumulation capacity and improves the photoelectric sensitivity characteristics.

[0010]

[Structure]

[Claim item 1]

In order to attain the above described purpose,

(1) in the amplification type solid state image pickup element equipped with photoelectric conversion unit which generates photoelectric charge dependent upon the incoming amount of light wherein, it introduces said photoelectric charge into the control input terminal of amplification element formed for each image concept and amplifies and reads the electric signals dependent upon the amount of incoming light, it is characterized such that it is comprised by capacitance part of photoelectric conversion unit which accumulates photoelectric charge generated by the aforementioned photoelectric conversion unit, capacitance part of amplification element in which is accumulated the photoelectric charge to be introduced into the control input terminal of amplification element, the optional control unit which enables the switching of electrical connection and disconnection of said both capacitance parts and is set up for each pixel; furthermore

(2) the magnitude of the accumulated capacity of photoelectric charge introduced into aforementioned amplification element is smaller than the capacity magnitude to be accumulated of photoelectric charge generated by photoelectric conversion unit;

(3) In addition to the control unit set up at each aforementioned pixel, other control unit which enables the electrical potential of control input terminal of amplification element to be fixed for optional period and to optional electrical potential.

[0011]

Figure 1 is a structure drawing to explain one embodiment of amplification type solid state image pickup element by this invention, and in the drawing, 101 is a semiconductor substrate, 102 high impurity density area, 103 gate oxide film, 104 a gate electrode, 105 interlayer insulating film, 106

metal electrode, 107 the second interlayer insulating film, 108 the second metal electrode, 109 a protective film. This invention relates to the structure in which light input circuit of amplification type solid state image pickup element, that is, photoelectric charge generated at photoelectric conversion unit is guided to the control input terminal, and particularly, it is not dependent on the method of signal output circuit on and after amplification element. Hence, even if the signal output circuit on and after amplification element adopts current detection method, or voltage detection method, or electric charge detection method, it can be applied to all the methods. Hereafter, architecture, structure, and equivalence circuit and the like of amplification type solid state image pickup element of this invention and the like will be explained in terms of light input circuit only.

[0012]

Semiconductor substrate 101 shows the semiconductor substrate by silicon and the like, and due to the intentional mixture of impurity elements such as boron and phosphorus and the like, it shows P type or n type semiconductor characteristics. High impurity density area 102 is the area where a large amount of aforementioned impurity element are particularly mixed, and electrical resistance is low, and constitutes the source electrode and drain electrode of Sc. And at PD unit, aforementioned impurity density area 102 takes on one edge of pn juncture which is the photoelectric conversion unit. Gate oxide film 103 shows gate oxide film of Sc or S1. Gate electrode 104 shows the gate electrode S1 or Sc, and normally polySi or **siliside,** or aluminum and the like are used. Gate electrode 104 plays the role of control input terminal of S1 or Sc. Interlayer insulating film 105 is the interlayer insulating film made up of SiO_2 and the like and is set up to respectively insulate drain electrode , gate electrode, and source electrode of Sc. Metal electrode 106 shows the electrode formed by metals such as aluminum and the like, and forms the S1 source electrode Sc drain

electrode. The second interlayer insulating films 107 are the second interlayer insulating film which insulates the metal electrode 106 and the second metal electrode 108 which plays the role of shielding the light of an optional location. Protective film 109 assures the reliability in the high temperature high moisture environment of the element and the like and is a protective film to prevent the destruction of the element by external factors, and normally silicon oxide film and silicon nitriding film are used.

[0013]

Figure 2 is the equivalence circuit of the light input circuit of amplification type solid state image pickup element of the structure shown in figure 1. PD shows the photoelectric conversion position generated by the photoelectric charge corresponding to the amount of incoming light, and S1 is the PD reset switch in order to fix one side of electrical potential Vp of PD and the electrical potential Vg of the control input terminal of the amplification element for an optional period to an optional electrical potential. Sc is the control unit which becomes the characteristics of this invention. Sc is set up to execute the electrical switching of connection and disconnection of capacitance part of amplification element and the capacitance part of photoelectric conversion unit wherein as to the capacitance part of amplification element , photoelectric charge generated at photoelectric conversion unit is accumulated in the photoelectric conversion unit, and as to the capacitance of amplification element, photoelectric charge introduced into the control input terminal of amplification element is accumulated in said amplification element.

Vg shows the electrical potential of control input terminal of amplification element, and is generated dependent on the incoming amount of the light to PD, and if the photoelectric charge accumulated in the capacitance part of photoelectric conversion unit is introduced to the control input terminal

of amplification element by Sc control, and accumulated in the capacitance part of amplification element, then, electrical potential of Vg changes, and output voltage or output current which matches the change portion of Vg is subjected to signal amplification, and is detected by the signal detection circuit on and after amplification element. φ1 and φ2 show the control input terminal of s1 and Sc respectively, and other side of electrical potential GND of PD is always grounded.

[0014]

Figure 3 (a)~ (d) shows the timing chart during the operation of solid state image pickup element of this invention described in claim item 1. The operations are divided in reset operation, first accumulation operation, second accumulation operation, and reading operation in summary, however reading operation follows the signal output circuit mode. In each time t1, t2, t3, and t4, the drawings of space electrical potential of photoelectric accumulation capacitance part of photoelectric conversion unit and photoelectric charge capacitance part of amplification element (hereafter called potential drawings) are shown in figure 4 (a) ~ (e). Solid state image pickup element of this invention has the characteristics of being equipped with light input circuit particularly, regarding rest operation. First accumulation operation, Second accumulation operation, the characteristics of solid state image pickup element of this invention will be explained using figure 2 ~ figure 4 (a) ~ (e) next.

[0015]

in the time period t1 of the reset operation, φ1 and φ2 are set up at the same time to the electrical potential of Vφ1(1) and Vφ2(1), thereby, other side of electrical potential Vp of photoelectric conversion unit PD and electrical potential Vg of control input terminal of amplification element are initialized to initial value Vrs(1). Next, while φ1 stays set to be at Vφ1(1), φ2 is set to be to the

electrical potential of Vφ2(3). Then, Sc becomes OFF state, Vg is fixed to Vgrs (1) and becomes floating state. Next, in the t2 period of resetting operation, by setting the Vrs to the electrical potential Vrs (2) different from Vrs(1), Vp is fixed to Vrs(2).

[0016]

in the first accumulation operation shown in t3, the electrical potential φ1 is set to be Vφ1(2), and S1 is set to be OFF state, thereby, Vp becomes floating state. At this time, as the incoming light enters the PD in reverse bias state, photoelectric charge Q1 which matches the incoming light amount is generated, one side of the photoelectrical charge of electron or positive electron hole is accumulated in the capacitance part Cst (1) of the photoelectric conversion unit. Thereby, the electrical potential of Vp changes by ΔVp dependent upon the Q1 and Cst(1). In the second accumulation operation shown by t4, by setting the electrical potential of φ2 as Vφ2 (2), potential barrier of Sc is decreased by the optional amount, photoelectric charge accumulated in Cst(1) is transferred to photoelectric charge accumulation capacitance part Cst(2) of the amplification element and accumulated. Thereby, the electrical potential Vg of the control input terminal of amplification element changes by Δvg dependent upon Q1 and Cst (2). Corresponding to the change of electrical potential of Vg, the electrical signals dependent on the light information by signal output circuit is amplified and detected.

[0017]

That is, in the solid state image pickup element described in claim item 1, as to the temporary accumulated capacitance Cst(1) of photoelectric charge generated dependent upon the incoming light amount by photoelectric conversion unit Pd, it can be considered as the sum total of PD capacitance Cpd, capacitance s1 Cc-d between S1 gate. Drain, capacitance S1 Cd-sub between

drain. Substrate, and capacitance scCg-s between Sc gate.source, and can be expressed as the following.

See the original formula (6)

Photoelectric charge accumulated in above described Cst(1) is set as Q1, then, the change amount ΔVp of electrical potential Vp becomes as follows:

See the original formula (7)

[0018]

Photoelectric charge accumulated in aforementioned photoelectric charge capacitance part Cst (1) is forwarded to the photoelectric charge capacitance Cst (20 of amplification element by the control of Sc. At this time, as far as capacitance Cst in which is accumulated the photoelectric charge, it can be considered as the sum total of capacitance scCg-d between Sc gates. Drain, capacitance sc Cd-sub between drain. Substrate and gate capacitance Cg of amplification element. And, in case juncture type electric field effect trandster or bipolar transistor and the like is used for amplification element, capacitance Cbg-sub between back gate. substrate is added, and is expressed as follows.

See the original formula (8)

Photoelectric charge amount accumulated in above described Csr (2) is equal to Q1, hence, the change amount ΔVg of the electrical potential of control input terminal of amplification element becomes as follows.

See the original formula (9).

[0019]

In the amplification type solid state image pickup element described in claim item 2, compared with the Cst(1), the characteristics of above described are that it can be made small. In the amplification

type solid state image pickup element described in claim item 2, compared with Cst (1), in order to make the Cst (2) smaller, it is effective if the structure is made such that gate capacitance of amplification element and the capacitance between the back gate-substrate is made smaller. For instance, as the amplification element, by using surface electric field effect type transistor (called MOS transistor in general), the said capacity can be made small. The gate capacity of the surface electric field effect type transistor depends on the magnitude of its element, and by making the element smaller, it can be made smaller optionally. And as the amplification element, in case juncture type electric field effect transistor and bipolar transistor are used, it is projected that Capacity between back gate-substrate and collector-substrate and the like would increase, compared with surface electric field effect type transistor, however, by adjusting the electrical potential difference between back gate-substrate or between collector-substrate, said capacity can be made smaller.

[0020]

That is, in case the photoelectric charge generated at PD unit is fixed, the smaller the Cst, the better the photo sensitivity. In the amplification type solid state image pickup element described in the claim item 2, it is Cst (2) < Cst (1), hence, according to the next formula (10), the value of ΔVc becomes larger than ΔVp, and even comparing with amplification type solid state image pickup element in claim item 1, photo sensitivity characteristics becomes larger furthermore.

See the original formula (10)

[0021]

Next, the structure and operation of amplification type solid state image pickup element of this invention described in claim item 3 is explained in the following. Figure 5 is the drawing showing the

structure of light input circuit unit of one pixel of amplification type solid state image pickup element described in the claim item 3. In the figure, 201 is a semiconductor substrate, 202 high impurity density area, 203 gate oxide film, 204 gate electrode, 205 interlayer insulating film, 206 a metal electrode, 207 the second interlayer insulating film, 208 the second metal electrode, and 209 a protective film.

[0022]

Semiconductor substrate 201 shows a semiconductor substrate by silicon and the like, and shows the semiconductor characteristics of p type or n type by intentionally mixing impurity such as boron or phosphorous and the like. High impurity density area 202 has low electrical resistance at the location where much of aforementioned impurity element is mixed particularly, thus constitute source electrode and drain electrode of S1 or Sc1 or Sc2 . And, at PD unit, same 202 takes on an edge of pn juncture which is a photoelectric conversion unit. Gate oxide film 203 shows gate oxide film of S1 or Sc1Sc2. Gate electrode 204 shows the gate electrode of S1 or Sc1 or Sc2, and usually polySi or siliside or aluminum and the like are used. Gate electrode 204 plays the role of control input terminal for S1 or, Sc1 or Sc2. Interlayer insulating film 205 is the interlayer insulating film made of SiO_2 and the like, and is set up to insulate source electrode, gate electrode, and drain electrode of S1 or Sc1 or Sc2. Metal electrode 206 shows an electrode formed by metals such as aluminum and the like, forms S1 source electrode, Sc1 drain electrode, and Sc2 source electrode and drain electrode. The second interlayer insulating film 207 are the second metal electrode 208 to play the role of light shielding of the optional locations and the second interlayer insulating film in order to insulate the metal electrode 206. Protective film 209 is the protective film to assure the reliability in the high temperature high humidity environment of the element and to prevent the

destruction of the element by external factors, and normally silicon oxide film and silicon nitrogen film are used.

[0023]

Figure 6 is a drawing showing the equivalence circuit of light input circuit of the amplification type solid state image pickup element of the structure shown in figure 5. PD shows the photoelectric conversion unit which generates the photoelectric charge corresponding to the amount of incoming light and S1 is the PD reset switch to fix other side of electrical potential Vp of PD for the optional period to the optional electrical potential Vrs1. Sc1 and Sc2 is the control unit which becomes the characteristics of this invention described in claim item 3. Sc1 is set up to electrically switch the connection and disconnection of the capacitance part of photoelectric conversion unit in which is accumulated the photoelectric charge generated at the photoelectric conversion unit, and the capacitance part of amplification element in which is accumulated the photoelectric charge introduced into the control input terminal of amplification element. Sc2 is set up in order to fix the electrical potential V6 of the control input terminal of amplification element for the optional period to the optional electrical potential Vrs2. Vg shows the electrical potential of the control input terminal of said amplification element and if photoelectric charge which is generated dependent on the amount of incoming light to PD and accumulated in the capacitance part of photoelectric conversion unit is guided to the control input terminal of amplification element by Sc3 and Sc2 control, and accumulated in the capacitance part of amplification element, electrical potential of Vg changes, output voltage or output current which matches the Vg change portion is subject to signal amplification, and is detected by the signal detection circuit on and after amplification element. $\varphi 1$, $\varphi 2$, and $\varphi 3$ show the control input terminal of S1, Sc1 and Sc3 respectively, and other electrical

potential GND of PD is always grounded.

[0024]

Figure 7 (a)~(d) is a drawing showing the timing chart during the operation of solid state image pickup element of this invention described in claim item 3. Operations are divided into resetting operation, the first accumulation operation, the second accumulation operation, and reading operation in summary, however, reading operation follows the formula of signal output circuit. In each time t1, t2, and t3, the potential drawings of photoelectric charge accumulation capacitance part of photoelectric conversion unit and photoelectric accumulation capacitance part of amplification element are shown in figure 8 (a)~(d). since solid state image pickup element of this invention has characteristics in light input circuit particularly, hence, regarding resetting operation, the first accumulation operation and second accumulation operation, the characteristics of solid state image pickup element of this invention will be explained using figure 6~ figure 8 (a)~(d).

[0025]

In the period t1 of resetting operation, by setting φ1, φ2 and φ3 at the same time to the electrical potential of Vφ1(2), Vφ2(2), Vφ3(1), other electrical potential Vp of photoelectric conversion unit PD is fixed to the initial value Vrs1 and the electrical potential Vg of the control input terminal of amplification element is fixed to the initial value Vrs. Next, in the first accumulation operation shown in t2, the electrical potential of φ1 and φ3 are set to be Vφ1(2), and Vφ3(2) respectively, and S1, sc2 are set as OFF, thereby, Vp and Vg become floating state respectively. At this time, as incoming light into PD in reverse bias state enters, matching with the amount of incoming light, photoelectric charge Q1 is generated. Either one of the charge of electron or positive electron hole is accumulated in the capacitance part Cst (1) of photoelectric conversion unit. Due to this,

electrical potential of Vp changes by ΔVp which is dependent on the Q1 and Cst (1). In the second accumulation operation shown by t3, the electrical potential of φ2 is set to be Vφ2(1), thereby, potential barrier of Sc1 is decreased by the optional value, and photoelectric charge accumulated in Cst(1) is transferred to photoelectric charge accumulation capacitance part Cst(2) of amplification element and accumulated. Thereby, the electrical potential Vg of control input terminal of amplification element is changed by ΔVg which is dependent on Q1 and Cst(2). Corresponding to the change of electrical potential of Vg, electrical signals dependent on the light information by signal output circuit is amplified and detected.

[0026]

That is, regarding the solid state image pickup element of this invention described in claim item 3, as to the capacitance Cst (1) in which the photoelectric charge generated dependent on the amount of incoming light at photoelectric convention unit PD is temporarily accumulated, it can be considered the sum total of Capacitance Cpd of PD, capacitance S1 Cg-d between gate and drain of S1, capacitance s1 Cd-sub between drain and substrate, and capacitance sc1Cc-s between gate and source of sc1. This can be expressed as follows (11):

See the original formula (11)

Suppose photoelectrical charge accumulated in above described Cst(1) is Q1, then change amount ΔVp of the electrical potential of vp becomes as follows.

See the original formula (12)

[0027]

The photoelectric charge accumulated in aforementioned photoelectric charge accumulation capacitance Cst (1) is forwarded to the photoelectric charge accumulation capacitance Cst (2) of the

amplification element by the control of Sc1. At this time, as to the capacitance Cst (2) in which photoelectric charge is accumulated, it is considered to be the sum total of capacitance Sc1Cg-d between gate and drain of Sc1, capacitance s1 Cd-sub between drain and substrate, and capacitance sc2Cg-d between gate and drain of sc2, Cd-sub of capacitance between drain and substrate, and gate capacitance Cg of amplification element. And, in case juncture type electric field effect transistor or bipolar transistor and the like are used as amplification element, capacitance between back gates-substrate Cbg-sud is added. It is expressed as follows:

See the original formula (13)

Photoelectrical charge accumulated in above described Cst (2) is equal to Q1 and the change amount ΔVg of the electrical potential of control input terminal of amplification element becomes as follows:

See the original formula (14).

[0028]

Next, the embodiment one will be shown as an embodiment of the amplification type solid state image pickup element of this invention described in the claim item 1 and claim item 2.

<Embodiment 1>

The amplification type solid state image pickup element of embodiment one is the area image sensor of the XY address type which read amplified optical information via vertical and horizontal scanning switch circuit, and signals detection method is current detection. Figure 9 is a drawing showing the structure of one pixel of the amplification type solid state image pickup element of the embodiment one, and in the figure, 301 is a semiconductor substrate, 302 (P+) area, 303 gate oxide film, 304 gate electrode, 305 interlayer insulation film, 306 metal electrode, 307 the second interlayer insulation

film, 308 the second metal electrode, 309 a protective film.

[0029]

Semiconductor substrate 301 shows a semiconductor substrate by n type silicon. (P+) area 302 is the location where particularly a large amount of boron is mixed using the ion injection method as the impurity element, and the electrical resistance is low. It constitutes the amplification element Amp of S1 and Sc and signal output circuit, and S2 source electrode and drain electrode. And at PD unit, aforementioned (P+) area 302 takes on one edge of pn Juncture which is the photoelectric conversion unit. Gate oxide film 303 shows gate oxide film of S1, Sc and Amp and S2. Gate electrode 304 shows the gate electrode of S1, Sc, Amp and S2, and polySi with phosphorus mixed in high density is used. Gate electrode 304 plays a role of control input terminal of S1, Sc, AmP, S2. Interlayer insulating film 305 is the interlayer insulation film of SiO2, and is set up to insulate source electrode, gate electrode, and drain electrode of S1, s2, Amp, and S2 respectively. Metal electrode 306 shows the electrode formed by aluminum and forms the source electrode of S1, drain electrode of Sc, drain electrode of Amp, and drain electrode of S2. Second interlayer insulating film 307 is the second interlayer insulation film in order to insulate metal electrode 306 and aluminum second metal electrode 308 which plays the role of light shielding at optional locations. Protective film 309 assures the reliability in the high temperature high humidity environment by external factors and the like, and silicon nitriding film is used.

[0030]

Figure 10 is the drawing showing the electrical equivalence circuit of the amplification type solid state image pickup element of embodiment 1. The area shown by dotted lines corresponds to one pixel of area image sensor. In figure 9 and figure 10, PD is formed by the pn Juncture using the n

area of semiconductor substrate and 302 (P+) areas. S1, s2, S3, Sc and Amp are formed by channel MOS transistor respectively. S1 plays the role of resetting switch of PD, and S2 has the role of selecting the row of pixels to be read. S3 has the role of sequentially switching the pixels to be read in the selected nth row. Sc shows the control unit which is the characteristics of this invention, and Amp is the amplification element to amplify and read the optical information signals.

S2 is selected by vertical scanning circuit and s3 uses the method selected by horizontal scanning circuit. Vh shows the voltage of 5V and provides the electrical potential of the one side of PD and source electrical potential of amplification element AMP.

[0031]

Figure 11 (a) and (b) are the drawings showing timing chart in which during operation time of solid state image pickup element of embodiment 1, one pixel is focused on. Figure 12 (a)~(d) shows the potential drawing of photoelectric charge accumulation capacitance part of the amplification element and the photoelectric charge accumulation capacitance part of photoelectric conversion unit at t1, t2, t3, and t4. During the period of t1 of resetting operation, Vrs is set to be 0V, and φ1 and φ2 are set to be 0V of electrical potential respectively, thereby, one side of electrical potential vp of PD and electrical potential vg of control input terminal of Amp are reset to be 0V. Next, while φ1 is set to be 0V, φ2 is set to be electrical potential 5V. Then, Sc becomes OFF state, Vg gets fixed at 0V and becomes a floating state. Next, during t2 period of resetting operation, by setting Vrs to 2V, Vp is fixed at 2V.

[0032]

In the period of the first accumulation operation shown in t3, the electrical potential of φ1 becomes 5V, and s1 is in OFF state, Vp is in the floating state fixed at 2V per one hour. At this time, by

having the incoming light into PD in reverse bias state, photoelectric charge Q which matches the amount of incoming light is generated, and charge of positive electron hole is accumulated in the capacitance part Cst(1) of the photoelectric conversion unit. Thereby, the electrical potential of vp changes by ΔVp dependent on Q1 and Cst(1). In the period of second accumulation operation shown by t4, by setting the electrical potential of φ2 to an optional electrical potential Vφ2(2), potential barrier of Sc decreases to 2V, and photoelectric charge accumulated in Cst(1) transfers to photoelectric charge accumulation capacitance part Cst (2) and is accumulated. Thereby, electrical potential Vg of the control input terminal of amplification element changes by ΔVg dependent on Q1 and Cst(2).

[0033]

In the period of reading operation, S2 of each pixel of the rows to be read by selection by vertical scanning circuit are set to be all OFF state. During that period, if S3 is set to be ON state by each pixel sequentially, each pixel in the row to be read can be read sequentially. At this time, the current which flows in Vout is dependent on the change portion ΔVg of electrical potential Vg of the control input terminal of Amp of each pixel and changes values. That is, optical information signals of PD is outputted sequentially by amplifying the current. And, output current is flown to resistance Rl and outputted as voltage at the end. As to the solid state image pickup element of this invention shown in embodiment 1, in the dark state, maximum current flows and as the incoming amount of light increases, output current decreases, showing the negative type characteristics.

[0034]

Next, the difference of the photo sensitivity between the embodiment 1 and the prior art is shown in the table 1 below.

[0035]

[Table 1]

The difference of the photo sensitivity between embodiment 1 and the prior art

	Prior art	Embodiment 1
Q	1.2×10^{-14} C	1.2×10^{-14} C
Cst	4.2×10^{-14} fF	1.2×10^{-14} fF
ΔVp	0.286 V	0.324 V
ΔVc	0.286 V	1.000 V
Photo sensitivity characteristics	5.72 V/1x.sec	20.0 V/1x.sec

[0036]

And, in table 1 are also shown, in combination, the change amounts of the maximum exposure amount of the incoming light per pixel at 1001x, the photoelectric charge amount Q in which the optical accumulation time per pixel emits during 0.5 millisecond, and the photoelectric charge accumulation amount Cst per pixel, and the change amount ΔVp of Vp and the change amount of Vg. In table 1, as to the photoelectric charge accumulation capacity of the prior art, PD capacitance value 30fG, Amp gate capacitance value 5fF, capacitance 2fF between gates. Drain of S1, and capacitance 5fG between drain. substrate are added up. And as to the photoelectric charge accumulation capacitance of embodiment 1, gate capacitance value of Amp, capacitance 2fF between Sc gates. Drain, capacitance 5fF between drawings. Substrate is added up. And, as Amp, MOS transistor was used, this is different from juncture type electric field effect transistor or bipolar transistor, and the junction capacity with substrate and backdate or collector can be ignored

naturally. According to the table 1, by using the embodiment 1, one can tell that photo sensitivity characteristics have improved 3.5 times more.

[0037]

As the embodiment of the amplification type solid state image pickup element of this invention described in claim item 3, embodiment 2 is shown.

<embodiment 2> As to the amplification type solid state image pickup element of embodiment 2, optical input circuit of the embodiment 1 is modified so as to have the characteristics of claim item 3, signals detection method and each layer structure are the same as ones in embodiment 1. Figure 13 is the drawing showing the structure of one pixel of the amplification type solid state image pickup element of embodiment 2, and figure 14 is the drawing showing its equivalence circuit, figure 15 (a)~(e) shows the timing chart in which one pixel is focused. IN the figure, 401 is a n type silicon substrate, 402 (P+) area, 403 gate oxide, 404 gate electrode, 405 an interlayer insulation film, 406 metal electrode, 407 the second interlayer insulation film, 408 the second metal electrode,409 a protective film.

[0038]

PD is formed by pn Junction using the (P+) area 402 with n area of semiconductor substrate. S1, s2, S3, Sc1, Sc2, Amp are formed by p channel MOS transistor respectively. Same as embodiment 1, S1 performs the role of resetting switch of PD, s2 has the role of selecting the rows of pixels to be read, and S3 has the role of sequentially switching the pixels to be read in the nth rows selected. Sc1, and Sc2 show the control unit which is the characteristics of this invention, and Amp is the amplification element which amplifies the optical information signals and reads. S2 is selected by the vertical scanning circuit and S3 uses the method to be selected by horizontal scanning circuit.

Vh shows 5V voltage, and provides the source electrical potential of amplification element Amp and the electrical potential of one side of PD. Vrs is always set to be the electrical potential 2V. Φ1, φ2, φ3, φ4, and φ5 show the electrical potential of control input terminal of S1, Sc1, Sc2, S2 and S3 respectively.

[0039]

Figure 16(a)~(c) shows the potential drawing of photoelectric charge accumulation capacitance part of photoelectric conversion unit and photoelectric charge accumulation capacitance part of the amplification element in respective operation time t1, t2 and t3 of the timing chart of figure 15.. In the period of t1 of resetting operation, by setting the φ1, φ2, and φ3 to the electrical potential of 0V, 5V and 0V respectively at the same time during t1 period of resetting operation, one side of electrical potential Vp of PD is reset to initial value 2V, and the electrical potential Vg of control input terminal of Amp is reset to the initial value 0V. Next, in the first accumulation operation shown in t2, the electrical potential of φ1 and φ3 are set to be 5V respectively at the same time, and s1 and Sc2 are set to be OFF state, thereby Vp and Vg becomes floating state respectively. AT this time, lights enters into PD in reverse bias state, thereby photoelectric charge Q which matches incoming light amount is generated, the charge of positive electron hole is accumulated in the capacitance part Cst (1) of photoelectric conversion unit part. Thereby, the electrical potential of Vp changes by ΔVp dependent upon Q1 and Cst(1). In the second accumulation operation shown in t3, by setting the electrical potential of φ2 to Vφ2 (1), the potential barrier of Sc1 decreases by optional amount, the photoelectric charge accumulated in Cst(1) transfers to the photoelectric charge accumulation capacitance part Cst (2) and is accumulated. By this, the electrical potential Vg of control input terminal of amplification element changes by ΔVg dependent upon Q1 and

Cst(2). As to the reading operation, it is the same as in embodiment 1, hence omitted.

[0040]

Next, table 2 shows the photo sensitivity of embodiment 2 and the prior art.

[0041]

[Table 2]

The difference of the photo sensitivity characteristics between embodiment 2 and the prior art

	Prior art	Embodiment 1
Q	1.2×10^{-14} C	1.2×10^{-14} C
Cst	4.2×10^{-14} fF	1.2×10^{-14} fF
ΔVp	0.286 V	0.324 V
ΔVc	0.286 V	0.726 V
Photo sensitivity characteristics	5.72 V/1x.sec	14.1 V/1x.sec

[0042]

And, in table 2 are also, in combination, shown the maximum exposure amount of the incoming light per pixel at 1001x, the photoelectric charge amount Q in which the optical accumulation time per pixel emits during 0.5 millisecond, and the photoelectric charge accumulation amount Cst per pixel, and the change amount of the change amount of Vg of Vp. In table 2, as to the photoelectric charge accumulation capacity of the prior art, same as the embodiment 1, it is 42fF. And, photoelectric charge accumulation capacitance of embodiment 2 is done by adding up Amp gate capacitance value 5fF, capacitance 2fF between gates. Drain of S1, and capacitance 5fG between drain. Substrate, and capacitance 5fF between gate.source of Sc2.

According to the table 2, by using the embodiment 2, one can tell that photo sensitivity characteristics have improved 2.5 times more.

[0043]

[Effects]

As made clear from the above explanation, according to this invention, there are following effects.

(1). The effects which correspond to claim item 1: In general, Cpd and Cg shows larger value by 1~2 digits, compared with s1Cc-d, or scCd-sub, or scCg-s, or scCc-d or scCd-sub, and occupies a large potion of the accumulation capacitance. It is a rare occasion that in case juncture type electrical field effect transistor or bipolar transistor are used as amplification element, the increase of the ratio occupied by accumulation capacitance of Cbg-sub is generated. As in the traditional element, in case the photoelectric charge accumulation capacitance part of PD unit and the photoelectric accumulation capacitance part of amplification element are ON state always, the magnitude of capacitance of accumulation capacitance part shows a large value since they contain Cpd and Cg always, thus ending up with a small change amount ΔVg of the electrical potential of control input terminal of amplification element. As against it, in the amplification type solid state image pickup element described in claim item 1 of this invention, the photoelectric charge accumulation capacitance part of PD unit and the photoelectric charge accumulation capacitance part of amplification element can be electrically disconnected , photoelectric charge accumulation capacitance does not contain Cpd, thereby, photoelectric charge accumulation capacitance in amplification element becomes smaller by the capacitance of Cpd portion at least, then, compared with traditional element, ΔVg can show a large value. As to the fact that the change portion ΔVg of Vg dependent upon the incoming light amount shows a large value, it shows that photo sensitivity

has improved that much and this is an advantage of this invention.

(2). The effect which corresponds to the claim item 2. In case the photoelectric charge generated at PD unit is fixed, the smaller the Cst, the better the photo sensitivity. As to the amplification type solid state image pickup element described in claim item 2, it is $Cst(2) < Cst(1)$, hence, the value of ΔVg becomes bigger than ΔVp, hence, compared with the amplification type solid state image pickup element in claim item 1 also, photo sensitivity becomes bigger furthermore.

(3). the effects which correspond to claim item 3: in general, compared with other capacitance, Cpd and Cg show larger value by 1~ 2 digits and occupy the large portion of accumulation capacitance. It is a rare occasion that in case juncture type electrical field effect transistor or bipolar transistor are used as amplification element, the increase of the ratio occupied by accumulation capacitance of Cbg-sub is generated. As in the traditional element, in case the photoelectric charge accumulation capacitance part of PD unit and the photoelectric accumulation capacitance part of amplification element are ON state always, the magnitude of capacitance of accumulation capacitance part shows a large value since they contain Cpd and Cg always, thus ending up with a small change amount ΔVg of the electrical potential of control input terminal of amplification element. As against it, in the amplification type solid state image pickup element described in claim item 3 of this invention, the photoelectric charge accumulation capacitance part of PD unit and the photoelectric charge accumulation capacitance part of amplification element can be electrically disconnected , photoelectric charge accumulation capacitance does not contain Cpd, thereby, photoelectric charge accumulation capacitance in amplification element becomes smaller by the capacitance of Cpd portion at least, then, compared with traditional element, ΔVg can show a large value. As to the fact that the change portion ΔVg of Vg dependent upon the incoming light amount shows a large value,

it shows that photo sensitivity has improved that much and this is an advantage of this invention. Furthermore, in the amplification type solid state image pickup element described in claim item 3, as the electrical potential for resetting the Vp and Vg, fixed electrical potential Vrs1 and Vts2 can be used respectively. Regarding the amplification type solid state image pickup element described in claim item 1, as the resetting electrical potential, Vrs which changes cyclically had to be used, but using fixed electrical potential is enabled, and in comparison, control is easier.

[Simple explanation of drawings]

[Figure 1]

It is a drawing showing the structure of light entry circuit unit of one pixel showing one embodiment of amplification type solid state image pickup element by this invention.

[Figure 2]

It is a drawing showing the equivalence circuit of light entry circuit unit of the amplification type solid state image pickup element of this invention

[Figure 3]

It is a drawing showing the timing chart during the operation time of amplification type solid state image pickup element of this invention

[Figure 4]

It is a drawing showing the space electrical potential of the photoelectric charge accumulation capacitance of the amplification element and the photoelectric charge accumulation capacitance of photoelectric conversion unit during the operation of amplification type solid state image pickup element by this invention

[Figure 5]

It is a drawing showing the structure of the light input circuit unit of one pixel of other embodiment of amplification type solid state image pickup element by this invention

[Figure 6]

It is a drawing showing the equivalence circuit of light input circuit of one pixel of other embodiment of amplification type solid state image pickup element by this invention

[Figure 7]

It is a drawing showing the timing chart during the operation of other embodiment of amplification type solid state image pickup element by this invention

[Figure 8]

It is a drawing showing the space electrical potential drawing of the photoelectric charge accumulation capacitance part of amplification element and photoelectric charge accumulation capacitance part of photoelectric conversion unit during the operation of other embodiment of amplification type solid state image pickup element by this invention

[Figure 9]

It is a drawing showing the structure of light input circuit of one pixel of amplification type solid state image pickup element of this invention

[Figure 10]

It is a drawing showing the equivalence circuit of light input circuit unit of one pixel of concrete embodiment 1 of amplification type solid state image pickup element of this invention

[Figure 11]

It is a drawing showing the timing chart during operation of amplification type solid state image pickup element of figure 10

[Figure 12]

It is a drawing showing the space electrical potential of photoelectric charge accumulation capacitance of amplification element and the photoelectric charge accumulation capacitance part of photoelectric conversion unit during the operation of amplification type solid state image pickup element of figure 10

[Figure 13]

It is a drawing showing the structure of light input circuit unit of one pixel of other concrete embodiment 1 of amplification type solid state image pickup element of this invention

[Figure 14]

It is a drawing showing the equivalence circuit of light input circuit unit of one pixel of amplification type solid state image pickup element figure 13 of this invention.

[Figure 15]

It is a drawing showing a timing chart during operation of amplification type solid state image pickup element figure 13 of this invention

[Figure 16]

It is a drawing showing the space electrical potential of photoelectric charge accumulation capacitance of amplification element and the photoelectric charge accumulation capacitance part of photoelectric conversion unit during the operation of amplification type solid state image pickup element of figure 13

[Figure 17]

It is a drawing showing the structure of one pixel of a traditional amplification type solid state image pickup element.

[Figure 18]

It is a drawing showing the equivalence circuit of one pixel of a traditional amplification type solid state image pickup element.

[Explanation of symbols]

101.. semiconductor substrate, 102.. High impurity density area, 103... Gate oxide film, 104 gate electrode, 105... interlayer insulating film, 106... Metal electrode, 107.. The second interlayer insulating film, 108.. The second metal electrode, 109 protective films

[Figure 1]

[Figure 3]

Left to right

Top:

Second accumulation; reading; resetting operation, first accumulation operation

Second accumulation operation

Bottom:

Operation

[Figure 17]

light

[Figure 2]

[Figure 4]

Top to bottom

Potential barrier

Accumulated photoelectric charge

Left to right at the bottom

Photoelectric charge accumulation capacitance part of photoelectric conversion part

Photoelectric charge accumulation capacitance part of amplification element

[Figure 5]

light

[Figure 6]

[Figure 7]

Left to right

Top:

Second accumulation; reading; resetting operation, first accumulation operation

Second accumulation operation

Bottom:

Operation

[Figure 9]

Light

[Figure 8]

Top to bottom

Potential barrier

Accumulated photoelectric charge

Left to right at the bottom

Photoelectric charge accumulation capacitance part of photoelectric conversion part

Photoelectric charge accumulation capacitance part of amplification element

[Figure 10]

One pixel within the dotted lines

[Figure 11]

Left to right

Top:

Second accumulation; reading; resetting operation, first accumulation operation

Second accumulation operation

Bottom:

Operation

[Figure 12]

Top to bottom

Potential barrier

Accumulated photoelectric charge

Left to right at the bottom

Photoelectric charge accumulation capacitance part of photoelectric conversion part

Photoelectric charge accumulation capacitance part of amplification element

[Figure 13]

Light

[Figure 15]

Left to right

Top:

Second accumulation; reading; resetting operation, first accumulation operation

Second accumulation operation

Bottom:

Operation

[Figure 14]

One pixel within the dotted lines

[Figure 16]

Left to right at the bottom

Photoelectric charge accumulation capacitance part of photoelectric conversion part

Photoelectric charge accumulation capacitance part of amplification element

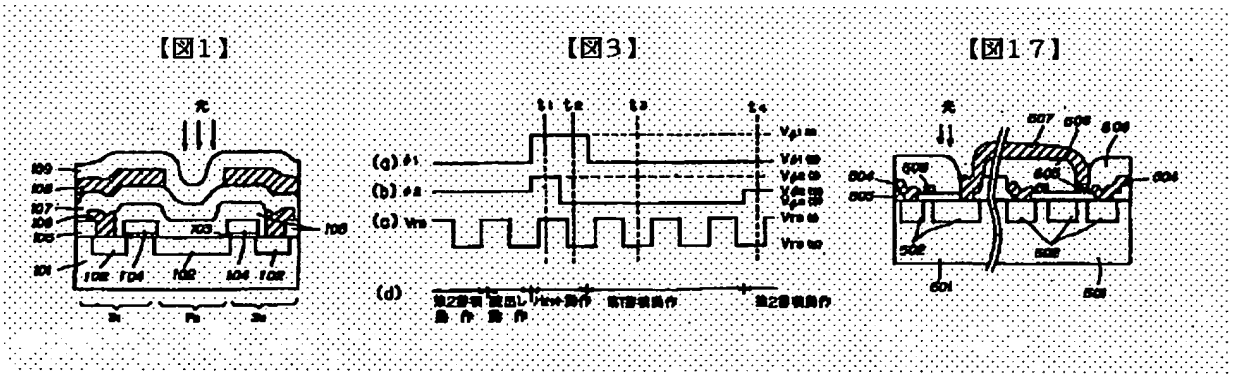
[Figure 18]

Top to bottom

Signal output circuit

One pixel (within dotted large frame) *on the right side*

Light input circuit *on the left side*



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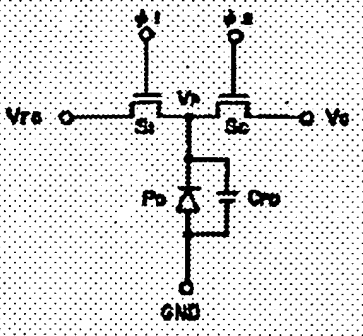

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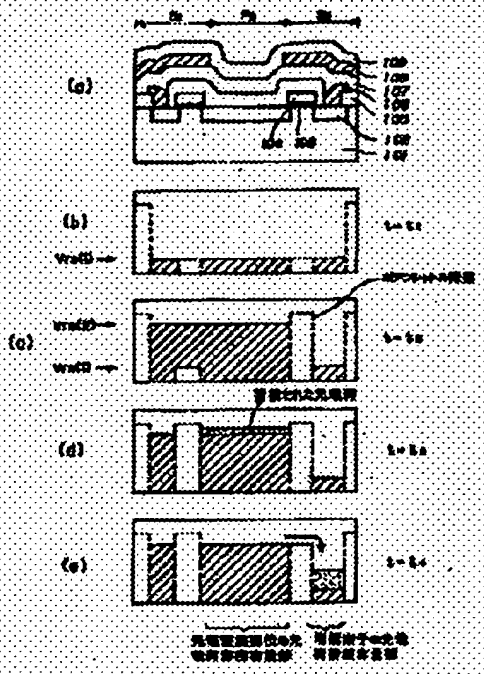

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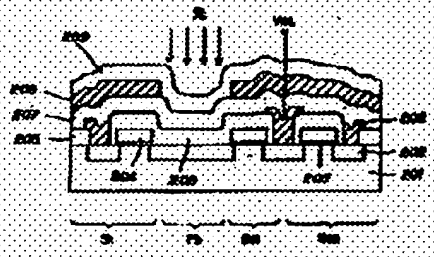

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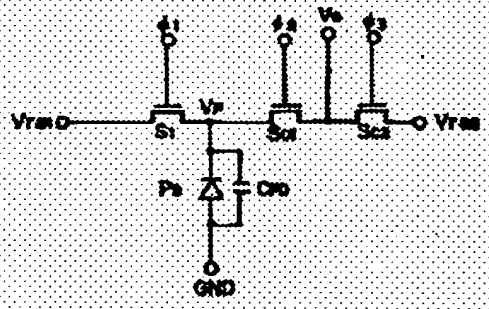

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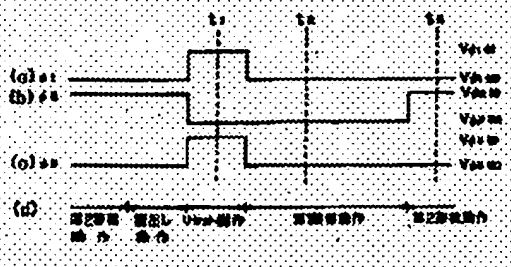

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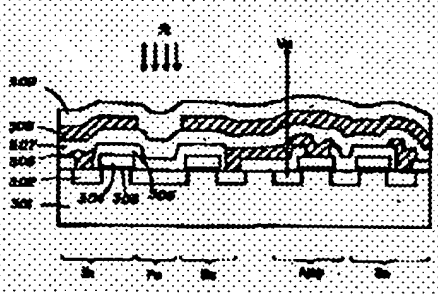

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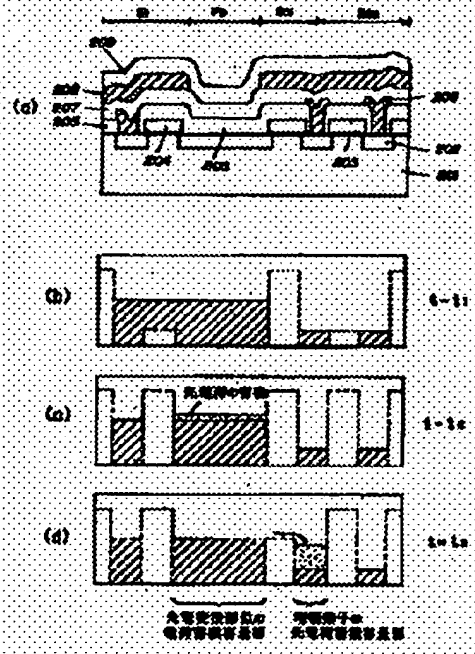
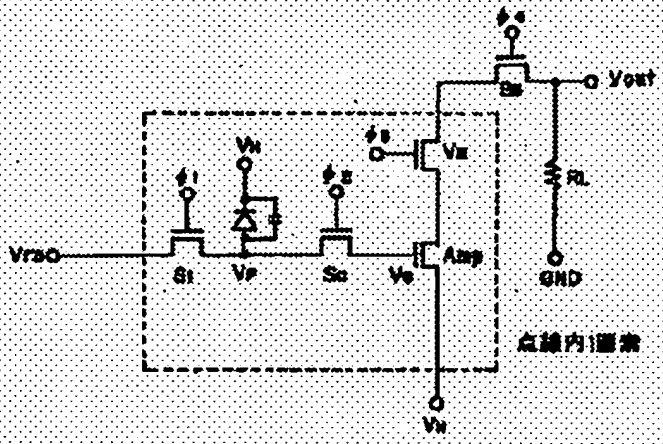


【図１０】



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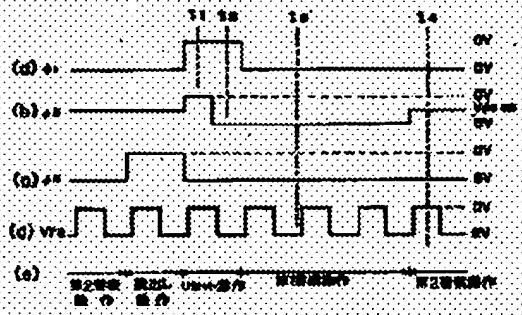

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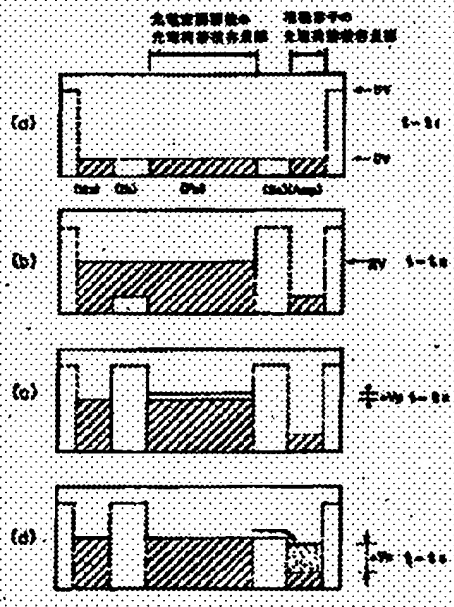

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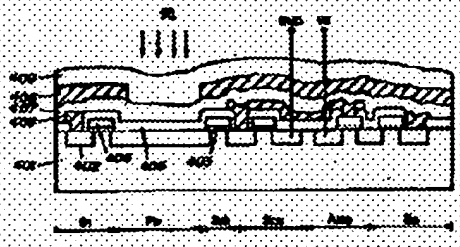

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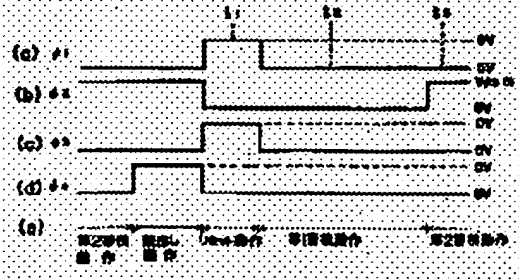

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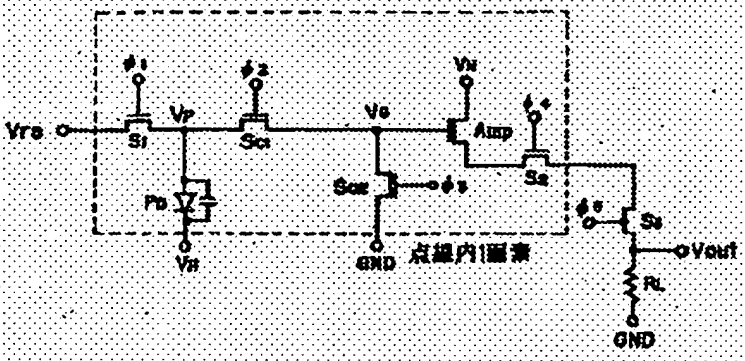
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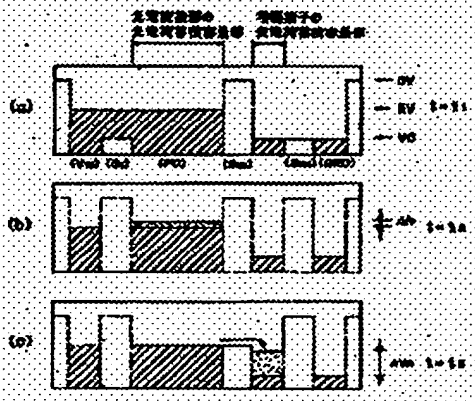
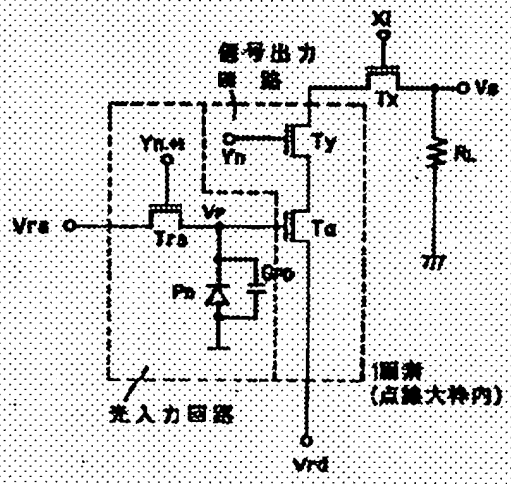
Vp
Vo
Amp
Scr
Scs
Sr
Ss
Pb
Vrt
GND
点線内1画素
Vout
RL
GND

【図１６】


(a)
(b)
(c)

【図１８】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(点線大枠内)
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Vrd